The Effects of the GAA15 on Lower Extremity Injury Incidence and Neuromuscular Functional Outcomes in Collegiate Gaelic Games.

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INTRODUCTION

Gaelic Football, Hurling, and Camogie (Gaelic Games) are Ireland's national field sports. Collectively known as Gaelic games, they are governed by the Gaelic Athletic Association (GAA). Gaelic games are popular both nationally and internationally, with over 2000 GAA clubs playing Gaelic games in Ireland and over 300 internationally (9). Additionally, collegiate higher education national leagues and championships take place annually with 136 teams in 44 higher education institutions involved (20). A fascination with the games is the speed in which they are played. The games are described as high intensity, multidirectional sports and require key skills such as speed, endurance, strength, and agility (15). They require short, fast intermittent movements such as jumping, catching, pivoting, sprinting, striking, and kicking, which coupled with the physical and biomechanical demands of the sports can increase an athlete's risk of injury (30). Therefore, it is logical that these key fundamental skills should be incorporated into a specific IPP in an attempt to prevent injury by influencing potential risk factors (2).

Intrinsic risk factors for injury include anatomical, biomechanical, hormonal, and neuromuscular variances (18). Factors such as excessive knee valgus motion, fatigue, training load, muscular imbalances, joint laxity and poor flexibility influence an athlete's risk of injury (18). However, neuromuscular variances or imbalances can be influenced by specific neuromuscular training (26, 13, 27, 1). Neuromuscular training enhances unconscious motor responses by stimulating afferent signals and central mechanisms responsible for dynamic joint control (24). Neuromuscular training incorporates balance, strength, flexibility, endurance and resistance training methods in an attempt to improve the nervous systems ability to generate fast and optimal muscle firing patterns to optimize movement patterns and skills (12, 24). Neuromuscular training programs are typically multi-intervention programs which include a combination of balance, weight, plyometric, agility and sport specific exercises (12).

Sports related injuries result in player, team, and institutional impacts; one of the most frustrating consequences of injury for athletes is the associated time loss from competition. Murphy et al., (17) reported that, over a 4 year period, 86% of injuries in Gaelic football resulted in an absence from participation lasting one week or more. On a more permanent basis, it has been reported that 20% of elite Gaelic footballers retire, and 17.5% change career due to injury (5). Additionally, the associated financial implications of sports related injuries and lengthy rehabilitation periods should be considered. The estimated annual cost of injury in Gaelic games exceeds €8 million with an average claim estimated at €1158.40 (25). The associated time loss from competition and from work has a direct financial implication of injury in Gaelic games which highlights the need for successful IPP's.

The epidemiology of injury in Gaelic games demonstrates that lower extremity injuries predominate (76% and 74.7% respectively in county/adolescent Gaelic football and 58% in adolescent hurling). The majority of the injuries in Gaelic games are non-contact in nature (68.7% in county Gaelic football and 64% and 63.3% respectively in adolescent Gaelic football and hurling). Hamstring injuries alone account for almost one quarter of all injuries in Gaelic football (17, 21, 16, 30). Also, the rate of injuries in adolescent, county and club level Gaelic games is significantly greater in matches than in training (17, 21, 30). This clearly identifies the relevance of preventative measures in an attempt to reduce the incidence of lower extremity, match play, and hamstring injuries, in particular, in Gaelic games.

The PEP program (Prevent Injury, Enhance Performance) (26) and the FIFA 11+ (13) are examples of commonly implemented IPPs. Neuromuscular training programs, such as the PEP and FIFA 11+, have been reported to significantly reduce the incidence of lower extremity injuries (10, 23), particularly Anterior Cruciate Ligament (ACL) injuries (26). The success of these programs, predominantly implemented with female athletes, was attributed to emphasis on correct landing technique and engaging correct hip, knee, and ankle positions during landing and cutting maneuvers. Avoidance of excessive knee valgus during landing and squatting techniques and increasing the strength of the hamstrings, hip abductor muscles, and gluteals was a focus of the program (26). Currently there is limited research into the effectiveness of such neuromuscular training programs in Gaelic games; however O'Malley et al., (22) recently investigated the effects of a structured IPP (GAA15) on neuromuscular function in collegiate Gaelic games players, concluding that implementation of the GAA15 for 8 weeks significantly improved players dynamic balance performance (22).

It is hypothesized that the implementation of the GAA15 program will reduce the incidence of injury in collegiate Gaelic games and positively affect lower extremity neuromuscular function by increasing Y-Balance scores in the intervention group compared to the control group.

METHODS

Experimental Approach to the problem

This prospective analytical observational cohort study adopted a non-randomized convenience sample. Participant assignment to the intervention or control group was based on geographical proximity to the research centre. Intervention and control group participants were gender, age and sporting discipline matched and participated in either a planned structured IPP intervention (GAA15) or their normal warm-up protocol.

The Institutional Review Board (IRB) at the Institute of Technology Carlow (ITC) approved this study and subjects were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study.

Pre and post season Y balance test measures were established to determine participants' dynamic balance, one of the key components of neuromuscular function (12). Hertel et al., (10) established the reliability of the anterior (ANT), posteromedial (PM) and posterolateral (PL) directions of the star excursion balance test (SEBT) and reported ICC values ranging from 0.78 to 0.96 for intra-rater reliability.

Throughout the season, incidence of injury was recorded on an online database system and injury rates (IR) were calculated per 1000 hours of participation to facilitate comparisons with previous epidemiological research.

Subjects

A total of 226 Gaelic games players participated in this investigation. A cohort of 154 players (mean age 20.3 ± SD 2.8 y) from the collegiate Gaelic games teams of ITC were allocated to the intervention group while an age and gender matched cohort of 72 players (mean age 20.6 ± SD 4.5 y) from the collegiate Gaelic games teams of Waterford Institute Technology (WIT) constituted the control group.

All participants were recruited for testing via text message. Prior to participation, each player was screened for current injuries, a medical/injury history assessment was conducted and each participant was informed about all testing procedures via a familiarization session by the primary researcher. Players were required to be at full fitness to be included in the investigation. Full fitness was defined as any player available for match selection and able to fully participate in training (17). The exclusion criteria included: current injuries that prevented participation in training or games, diagnosed balance disorders, diagnosed inner ear disorders, and recent surgeries (within the last six months). Overall, 65 players in the intervention group did not return for post-testing which resulted in a dropout rate of 42%. The participant dropout rate in the control group was also 42% (n=30). Therefore, the total number of participants used for analysis in the intervention and control groups were 89 and 42, respectively.

Procedures

Two separate days of performance testing using the Y balance test were required for this investigation. Pre-testing took place prior to the collegiate sporting season and post-testing took place at the end of the season when teams had played their final game. The average season length was 20.4 ± SD 2.4 weeks and on average teams had 17.8 ± SD 6.1 training sessions during the season. During pre-testing each player's limb length was measured; reach distance for the Y balance test is related to limb length (% Normalized Mean Reach Distance [%NMRD]). Testing began with a standardized warm-up followed by familiarization of the Y Balance test. Formal testing of the players took place within 10 minutes of familiarization and involved three trials in each direction (ANT, PM and PL) on each leg for the Y Balance test. All procedures were repeated during post-testing.

Y Balance Test Procedures:

Participants were instructed to remove their shoes, place their hands on their hips, and maintain single leg stance on the Y Balance test stance platform. Once participants were in the correct position, they were instructed to maintain single leg balance while simultaneously reaching the toes of their free limb towards the red border of the reach indicator in the direction being tested. Participants were instructed to push the reach indicator as far as they could in the test direction and the distance achieved was recorded using measures engraved on the pipes of the Y Balance test equipment (centimeters). The test trial was invalid and repeated if the participants fell from the stance platform, touched down their reach foot before the movement was complete, kicked the reach indicator, or were unable to return their reach foot to the stance platform under control.

Intervention:

The GAA15 warm-up was created for the intervention group. The GAA15 was the only warm up performed by the athletes in the intervention group for the duration of the collegiate season. Coaches were educated on the program through practical workshops and an informative DVD, and were requested to implement the program before every training session and match throughout the season. Compliance and consistency were key for this investigation, therefore coaches were mentored throughout the season on proper exercise execution via weekly visits to the training sessions by the primary investigator. The duration of the GAA15 was 11 minutes (Table 1) and the program incorporated a range of dynamic exercises, which followed the five main components of successful IPPs (26): 1. Avoid biomechanical positions associated with a high risk of injury; 2. Increase flexibility;

3. Improve strength and conditioning; 4. Optimize plyometrics; and, 5. Include sport specific agilities. For the duration of the season the control group was instructed to perform their normal warm up protocol which was of similar duration (11 minutes) to the intervention group, however the exercises performed during this timeframe were at the discretion of the coaches. The control groups warm up also incorporated dynamic exercises, however the main difference in the intervention groups warm up was the utilization of mini-band exercises, low-level plyometric exercises and full body dynamic stretches such as the world's greatest stretch.

INSERT TABLE 1 HERE

Injury Surveillance:

Injuries were documented for both groups on a weekly basis through an online database system by allied health care professionals working with the teams. Permission was granted from the Physiotherapy Department of the University College Dublin (UCD) to access and utilize the existing GAA injury surveillance database for this investigation. Specific injury definitions were defined and utilized as a method of consistently tracking injuries across all teams. These definitions were derived from a previous study investigating the incidence of injury in Gaelic football (17). An injury was defined as any injury which had been present for greater than 24 hours and prevented a player from fully participating in training or match play activities (17).

The severity of an injury was determined by a player's time lost from sport after injury. Severity was sub-classified as mild [21days] (28, 19). All clinical users of the database were contacted by telephone and informed of these definitions at the start of the season through an information document. They were asked to follow the definitions throughout the season when reporting injuries and to contact the primary investigator with any issues.

The injury data collected was translated into training and match play injury rates (IRs) and more specifically the site, mechanism and severity of injury were recorded. The IR per one thousand hours of participation, incidence proportion (IP), repeat incidence proportion (RIP) and injury rate ratio (IRR) were documented for both the control and the intervention group.

The Injury Rate (IR) per one thousand hours of participation was calculated using the following formula (14)

$$\boldsymbol{Number\ of\ Injuries \div Total\ hours\ of\ participation \times 1000}$$

95% confidence intervals were calculated using:

$$IR \pm 1.96 \times SE(IR)$$

while the standard error (SE) was measured using:

$$SE(IR) = \sqrt{Number\ Of\ Injuries} \div Total\ hours\ of\ participation$$

Incidence Proportion (IP) was calculated as follows (14):

$$\frac{\boldsymbol{Number\ of\ injured\ participants\ who\ sustain\ at\ least\ 1\ injury}}{\boldsymbol{Number\ of\ participants\ at\ risk\ of\ injury\ (total\ participants)}}$$

95% confidence intervals were calculated using:

$$IP \pm 1.96 \times SE(IP)$$

while the standard error (SE) was measured using:

$$\sqrt{\frac{IP \times (1 - IP)}{number\ of\ participants\ at\ risk}}$$

Subsequently, *Repeat Incidence Proportion* (RIP) was calculated as the value for incidence proportion does not take into account participants who may have sustained multiple injuries during the specific time frame.

$$\frac{\boldsymbol{Number\ of\ repeatedly\ injured\ participants}}{\boldsymbol{Number\ of\ participants\ injured\ overall}}$$

The final calculation was for the Injury Risk Ratio (IRR) (14). IRR is a measure of the difference in IR's between two groups:

$$\frac{IR\ Intervention\ group}{IR\ Control\ Group}$$

The significance levels for the difference in the IRR's between the intervention and control groups were calculated using VRP injury statistics software.

Statistical Analysis

All data was screened for normality using Shapiro-Wilk test for normality. Analysis of covariance tests (ANCOVA) were utilized to compare differences between the intervention group and the control group Y Balance test data. Composite Y balance scores were also calculated (sum of the 3 reach directions divided by 3x limb length x 100) and analyzed for comparison between groups. The level of significance was set at 5% ($p<0.05$).

RESULTS

Y Balance Performance

The results for the between-group effects are shown in figure 1. In the ANT reach direction, analysis of the results revealed increases in favor of the control group for both the right and left leg in comparison to the intervention group (Adjusted mean difference -2.2 %NMRD, p=0.002/-2.1 %NMRD, p=0.002 respectively). The results for PL reach distance showed increases in reach distance in favor of the intervention group and revealed a significant difference between the intervention and control groups post season scores on the left leg (1.7 %NMRD, p=0.034;) but not on the right leg (1.4 %NMRD, p= 0.128). Significant differences were also revealed for PM reach on the left leg (1.5 %NMRD, p= 0.043) but not the right leg (1.3 %NMRD, p= 0.112) in favor of the intervention group. There was also a significant increase in the Y Balance composite score for the intervention compared to the control group for the right (p=0.007) and left leg (p= 0.001; figure 2).

INSERT FIGURE 1 AND 2 HERE

Incidence of Injury

The overall IP for the intervention group was 12% (0.08 to 0.16) and the overall IP for the control group was 13% (0.08 to 0.18). Interestingly, the results showed that the RIP in the control group was twice as high as the intervention group (34% versus 14% respectively).

The final calculations in table 2 represent the IRR, which quantifies the variation in injury rates between two groups. The results show that overall there was a 66% reduction in the incidence of injury in the intervention group compared to the control (0.34; 0.21 to 0.55). Similarly, the IRR for training injuries showed a reduction in injuries of 80% (0.20; 0.09 to 0.40). However match play injuries decreased by 16% in favor of the control group (1.16; 0.54 to 2.48).

The most prevalent sites of injury in the intervention group were the hamstrings (0.62 injuries per 1000h) and the ankle (0.62 injuries per 1000h participation). Similarly, the most prevalent site of injury in the control group was the hamstrings, however the rate of hamstring injuries in the control group was almost twice as high as the intervention group (1.05 versus 0.62 injuries per 1000h participation). The IRR for hamstring injuries was 0.59 (0.19 to 1.89). Therefore, there was a 41% reduction in hamstring injuries in the intervention group compared to the control.

Knee injury rates in the intervention group were over 3 times lower than the knee injury rates in the control group (0.25 versus 0.79 injuries per 1000h participation). The IRR for knee injuries was 0.32 (0.07 to 1.42) which indicates a 68% reduction in knee injuries in the intervention group compared to the control.

Non-contact injuries predominated in both the control and the intervention group, however the rate of non-contact injuries in the control group was two and a half times greater than the intervention group (2.89 versus 1.12 injuries per 1000h participation). The IRR for non-contact injuries was 0.39 (0.18 to 0.82) which indicates a 61% reduction of noncontact injuries in the intervention group compared to the control.

INSERT TABLE 2 HERE

DISCUSSION

The findings suggest that incorporation of the GAA15 program into a team based warm-up can significantly reduce a player's incidence of injury and improve their dynamic balance performance, an aspect of neuromuscular function, in collegiate Gaelic games. Findings which are supported by the results of O'Malley et al., It was also evident that there was a reduction in the incidence of hamstring, knee and non-contact injuries in the GAA 15 intervention group when compared to the non-structured

warm up of the control group, supporting the utility and implementation of a neuromuscular training program such as the GAA15.

Improvements in dynamic balance performance have been reported in female soccer players participating in a neuromuscular training program similar to the GAA15 (6). Filipa et al. (2010) reported greater reach distances for PL (Right 12.0 %NMRD, p = 0.008 / Left 10.4 %NMRD, p=0.040) and PM (Left 12.6 %NMRD, p=0.028) directions in the intervention group compared to their gender and age matched controls. These changes were attributed to improved neuromuscular function and dynamic balance control in the intervention group. These findings corroborate with the balance improvements in this study (PL right, p= 0.034; PM right, p=0.043), supporting the hypothesis that lower limb dynamic balance was improved following implementation of the GAA15.

From this study it is evident that the Intervention group IRs (2.62 per 1000h) were almost three times less than the IRs in the control group (7.62 per 1000h). Previous epidemiological research identified an overall IR in Gaelic football of 8.25 injuries per 1000h participation (3); consistent with the control group's overall injury rate of 7.62 injuries per 1000h in this current investigation.

An IRR of less than one indicates a positive intervention effect (14), it can also be used to calculate the percentage rate difference between the intervention and control group (14). This information is fundamental to this study as it informs how effective the GAA15 was at preventing lower extremity injuries in collegiate Gaelic games athletes. The results of this study reported an overall IRR of 0.34 indicating a 66% reduction in injuries in the intervention group compared to the control group. In a systemic review by Hübsher et al., (12) it was reported that the implementation of a neuromuscular training program reduced lower extremity injuries by 39% (IRR 0.61); supporting the findings of this present study.

It is acknowledged that the risk of sustaining a hamstring injury in Gaelic games is high (3, 16, 17, 21); this study confirmed these findings. Although, hamstring injuries in this present study predominated in both groups, the intervention group had 41% less hamstring injuries than the control group. A 73% decrease in the number of hamstring injuries following the implementation of a sport specific training program (IRR: 0.27) was reported in Australian football players. These authors attributed the success of the sports specific training to improved hamstring muscle conditioning and improvements in fatigue resistance of the hamstrings (29). Additionally, it has been reported that multi-intervention programs incorporating sport-specific drills for hamstring flexibility while fatigued, sport skills that load the hamstrings, and high-intensity interval training to mimic match playing conditions reduces the incidence of hamstring injuries in Australian football (11).

The results of this study revealed that non-contact injuries in the intervention group were 61% less than that of the control group. This suggests that implementation of the GAA15 could potentially reduce non-contact injuries in Gaelic games by over half. Similar findings were reported following the implementation of a neuromuscular training program in female floorball players (23). Pasanen et al., (23) reported a 66% reduction in the number of non-contact injuries sustained by players in the intervention group compared to the control; these results are consistent with those in this current study. They attributed the reduction of non-contact injuries to improved motor skills and body control, and preparation of the neuromuscular system for sports specific maneuvers, factors which may have contributed to the observed results in this study.

Player non-compliance was a major limitation of the current study. This is evident from the participant drop-out rates. Both the intervention and the control group lost 42% of their participants from pre-season to post-season testing. A further limitation of this study may be the influence of training loads and history of injury on subsequent injury, which this current investigation did not measure. Higher training loads and previous history of injury have been identified as risk factors for injury, therefore such factors could influence the injury rate differences between the groups (8). As this investigation was an observational analytical cohort study which adopted a non-randomized convenience sample, the lack of randomization of the subjects and control of the warm ups for the control group are considered to be limitations of the study.

Overall, implementation of the GAA15 neuromuscular training program improved Y Balance performance and reduced the incidence of injury in collegiate Gaelic games. However, conduction of a Randomized Control Trial involving collegiate Gaelic games athletes with lower dropout rates is required to confirm these findings and the efficacy of the GAA15. Additionally, it would be beneficial to assess the effects of the GAA15 over a longer period of time and across different age groups to make comparisons between different cohorts of players. A further recommendation would be to investigate the effects of the GAA15 on other elements of neuromuscular function such as lower extremity strength, flexibility, and agility. In the future, a longitudinal study which monitors the effectiveness of the GAA15 from adolescence into adulthood may present a richer representation of its overall effectiveness, however it is clear from the results of this study that the implementation of the GAA15 program over one season in collegiate Gaelic games was beneficial to players as it decreased their incidence of injury and improved their balance performance.

PRACTICAL APPLICATIONS

These results are relevant for team-based sports as the GAA15 is easily implemented into field sessions, requires no additional equipment, takes no more than 15 minutes complete, and successfully reduces the incidence of injury.

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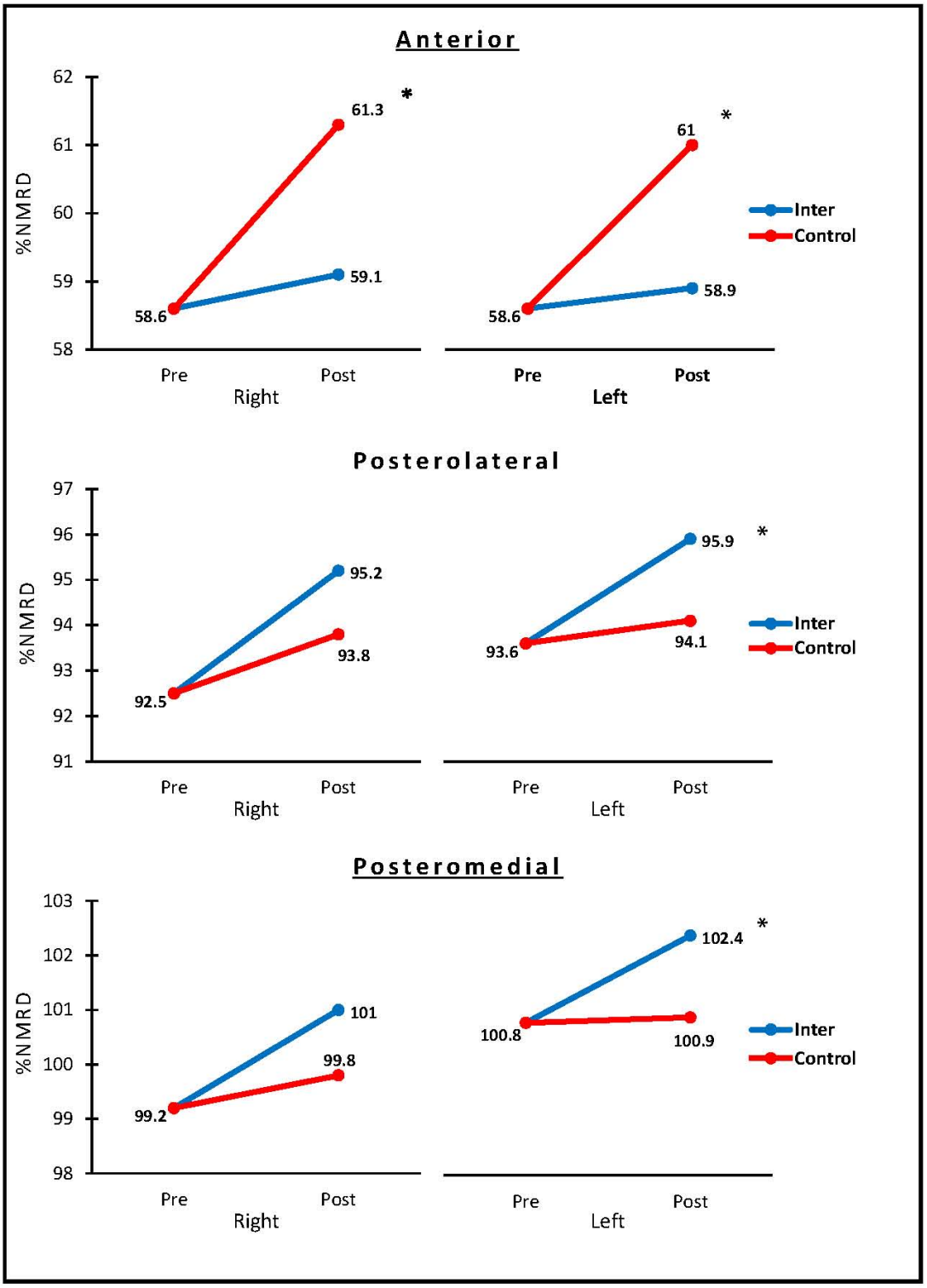
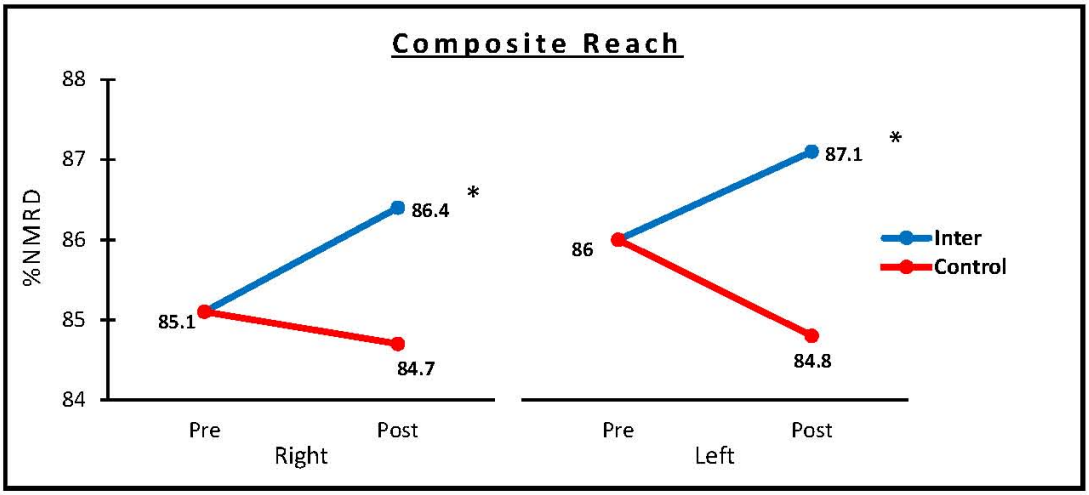


%NMRD= percentage neuromuscular reach distance; Inter= intervention group; Control= control group; *= statistical significant difference between intervention and control group ($p<0.05$); Right= right stance limb; Left= left stance limb; PRE= pre-testing; POST= post-testing.

Figure 1: Estimated marginal means for anterior, posterolateral and posteromedial Y balance scores for the intervention and control group.



%NMRD= percentage neuromuscular reach distance; Inter= intervention group; Control= control group; *= statistical significant difference between intervention and control group ($p<0.05$); Right= right stance limb; Left= left stance limb; PRE= pre-testing; POST= post-testing.

Figure 2: Estimated marginal means for Composite Y balance scores for the intervention and control group.

Table 1: GAA15 protocol

Goals	Exercises	Duration (seconds)	Section time (minutes)
Warm Up	**A. Forwards/Backwards Jog 10m** Jog straight line out 10 metres and jog backwards to starting line. Do not let knees buckle inwards	A. 30	2
	B. Lateral skip With legs shoulder width apart, shuffle sideways bringing feet together and then apart. Do not twist upper body or let knees buckle inwards.	B. 30	
	C. High Knees and Heel Flicks For high knees bring knee up to hip height ensuring 90ºof hip and knee flexion. Keep core tight and alternate legs. For heel flicks, bring heels towards glutes at 0º of hip flexion. Keep core tight and alternate legs	C. 60	
Dynamic Stretching	**A. World's Greatest Stretch** Hug knee into chest and hold for 1 second. Then place same foot onto ground into a lunge position and hold. Place both hands on the inside of the leg and rotate the arm closest to the knee into full abduction. Rotate back and place arm on the outside of the knee. Sit back into a hamstring stretch and push through back leg to finish the stretch. Repeat on the opposite side.	A. 60	5
	B. Inch Worm with Push Up Standing tall and keeping legs straight place hands on ground in front. Walk hand out as far as possible, perform a push up and walk legs in towards arms into starting position.	B. 60	
	C. Superman, Reverse Lunge with Rotation Perform single leg Romanian deadlift reaching arm and leg as far as possible in each direction. Maintain balance and place back foot onto ground into a lunge position. Rotate arm and chest to right and left and repeat on opposite side.	C. 60	
	D. Lateral Lunge Side step into a lunge position ensuring both feet are pointing forwards. Push back up to start position using bent knee and repeat on other side.	D. 60	
	E. Superman, explosive hip flexion and lunge Perform single leg Romanian deadlift reaching arm and leg as far as possible in each direction. Bring non-stance leg up into chest at speed and hold for 1 second. Then place same foot onto ground into a lunge position and hold.	E. 60	

Activation (Mini-Band Exercises)	The starting position for all mini band activation exercises (A-E) is to place the mini band above the knees, keep legs shoulder width apart, and sit into a mini squat position with a slight bend in the knees. Hold head and chest up, and keep toes pointing forward throughout the exercises. It is important that tension is kept on the band for the duration of each exercise		
	A. Hip Dissociation From the starting position slowly drop one knee at a time inwards into internal rotation and push knee outwards into external rotation against the bands resistance.	A. 30	
	B. Forwards/backwards band walks From the starting position walk slowly forward and ensure knees push out against the bands resistance. After 15 seconds repeat walking backwards.	B. 30	
	C. Lateral band walks From the starting position take mini steps sideways to the right. Ensure tension is kept on the band throughout by pushing knees out against the bands resistance. After 15 seconds repeat by walking sideways to the left.	C. 30	2.5
	D. Split band Walks From the starting position place one foot in front. Hold legs shoulder width apart and maintain a slight bend in both knees. Slowly walk forward, leading with the front foot each time. After 8 steps forward take 8 steps backwards leading with the back foot. Change the leading foot and repeat on the opposite side.	D. 30	
	E. Single leg bounds with mini band From the starting position jump in a diagonal direction and land on one foot and maintain balance. Do not let knee buckle inwards and maintain tension on band throughout. Hold single leg stance position for 1 second and jump in a diagonal direction onto the opposite leg.	E. 30	
Sports Specific	**A. Fast Feet and Sprint** Start with legs shoulder width apart and sit into a mini squat position. Keep head and chest up. Run on the spot as fast as possible ensuring minimal ground contact time with each foot. Perform for 10 seconds and sprint 5 metres. Repeat twice.	A. 30	
	B. Linear Hop Keep arms overhead. The aim is to push as high off the ground as possible on each leg, one after the other, bringing knees to hip height. The action should mimic a slow single leg hop.	B. 30	1.5
	C. Linear Skip Begin by moving right hip up to hip level. With speed change legs by bringing left leg up to hip level and pumping the arm through the movement in a linear direction. The movement should mimic a fast march	C. 30	

with minimal ground contact time.

Total	11

Table 2: Injury Rate, Incidence Proportion and Repeat Injury Proportion for the intervention and control group.

	Intervention Group					Control Group							
	IR	**CI**	**IP**	**CI**	**RIP**	**IR**	**CI**	**IP**	**CI**	**RIP**	**IRR**	**CI**	**p**
Training	**1.24**	1.9 0.6				**6.39**	9.4 3.4				**0.20**	0.40 0.09	**0.001***
Matches	**14.41**	20.2 8.6				**12.42**	20.5 4.3				**1.16**	2.48 0.54	**0.697**
Overall	**2.62**	3.4 1.8	**0.12**	0.16 0.08	**0.14**	**7.62**	10.4 4.8	**0.13**	0.18 0.08	**0.12**	**0.34**	0.55 0.21	**0.001***